Regional Monitoring of Southern California's Coastal Watersheds

Stormwater Monitoring Coalition
Bioassessment Working Group

FINAL DRAFT

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Introduction

Watersheds in the coastal range of southern California are a valuable aquatic resource. Comprising over 5,000 stream miles, both humans and wildlife use these watershed resources for fish habitat and fishing, drinking water, swimming and other recreational uses, water augmentation and groundwater recharge, agriculture, and many others.

Despite the many beneficial uses derived from the rivers and streams, southern California's burgeoning population also places a large number of potential stressors on its coastal watersheds. Habitat alteration, hydromodification through increased imperviousness, flood control, water augmentation and diversion, discharge of treated and industrial wastewaters, and contributions from urban runoff can all result in impairments to aquatic life in the region's rivers and streams.

At this point in time, the regional health of southern California's rivers and streams cannot be determined. One reason the regional health cannot be determined is because so little of the region's streams and rivers are monitored. Based on existing monitoring effort, only 29% the stream miles in southern California are monitored on an ongoing basis. Some watersheds, such as the San Gabriel River have many sampling locations and are well-monitored, but the status of other watersheds like Calleguas Creek remain virtually unmonitored. The reason for this uneven level of effort is due mostly to the presence of instream discharges, where monitoring is mandated. Otherwise, monitoring is typically not conducted. As a result, the most monitoring occurs in locations where impacts are expected to occur and the potential for a biased picture of aquatic health is likely.

Even if expansive monitoring programs of aquatic health were conducted, the monitoring is currently conducted by over a dozen different organizations. Each of these organizations has disparate programs that vary in design, frequency, and indicators selected for measurement. Even where designs are similar, often the field techniques, laboratory methods, and quality assurance requirements are not comparable so cumulative assessments are infeasible. Finally, assuming all programs were of comparable design and quality, there is no overarching information management system so sharing data is extremely labor intensive if not entirely impracticable.

The goal of this document is to describe a large-scale, regional monitoring program of southern California's coastal streams and rivers. The objective is to create a comprehensive monitoring design that integrates many elements of the individualized monitoring programs that currently exist within the region. As part of this design, a necessary component will facilitate comparability in the field and the laboratory, set performance-based QA guidelines, and initiate an information management system for sharing data. Data analysis elements will be described for creating assessment endpoints of stream health. This integrated regional monitoring program is designed to be collaborative, so that each individual program can assess their local geography, then contribute their portion to the whole of the region to address large-scale management

needs and provide answers to the public about the health of southern California's streams and rivers.

The motivation behind the integrated regional watershed monitoring is the Stormwater Monitoring Coalition (SMC) and the Surface Water Ambient Monitoring Program (SWAMP). The SMC is a coalition of stormwater management agencies and Regional Water Quality Control Boards (RWQCBs) from Ventura to San Diego (Table 1). Unlike any other organization in the United States, the SMC's mission is to cooperatively answer the technical questions that enable better environmental decision-making regarding stormwater management. The SWAMP is a statewide receiving water monitoring program administered by the Sate Water Resources Control Board (SWRCB). The two programs effectively cross paths in the area of wadeable streams in southern California with the parallel objective of assess health of the region's aquatic resources. As such, the two programs have joined forces to create the regional watershed monitoring program described herein.

MONITORING QUESTIONS AND GENERAL APPROACH

The Regional Watershed Monitoring Program addresses three questions of importance to regulated agencies, regulatory organizations, and public:

1. What is the condition of streams in Southern California?
2. What are the major stressors to aquatic life?
3. Are conditions in locations of special interest getting better or worse?

Each of these questions is answered by a different component of the monitoring program. Together, these components determine the spatial and temporal extent of impacts, their magnitude, and potential causes.

The first question addresses the magnitude and spatial extent of impacts of all streams in the region using a probabilistic sampling design. The goal will be to achieve an estimate of impacted stream miles at varying severity of impairment. In addition, the spatial extent of impact will be compared among watersheds and land uses. Therefore, stratification of the probabilistic design will occur across 15 different watershed areas that are defined by management units. Stratification will also occur across three different land uses defined as urban, agricultural, and open. At each site, multiple indicators will be used to assess the ecological health of the stream including water chemistry, aquatic toxicity, benthic macroinvertebrate community structure, periphyton, and physical and riparian habitat. Impacts will be defined by thresholds for each indicator, such as comparison with established benchmarks or standards for water quality. Macroinvertebrate communities will be evaluated by calculating the Southern California Index of Biotic Integrity (IBI, Ode et al. 2005) and by multivariate tools, such as the RIVPACS ratio of observed to expected taxa (O/E, Hawkins et al. 2000).

The second question addresses the stressors that affect the health of streams in Southern California. The goal of this component is to build upon the stressor and response data collected in the first component to develop a relative risk index (Van Sickle et al. 2006). The response variables will focus on ecological health endpoints such as biological measures of assemblage metrics or indices (i.e., IBI or O/E). Example stressors will include elevated nutrients, trace metals, degraded physical habitat, and increased toxicity. The relative risk of each stressor will be calculated by comparing the ecological health response variables at sites where the stressor is above or below thresholds of concern. This component requires no sampling effort beyond that required by the first component, but merely a more thorough analysis or the data.

The third question addresses the temporal changes in stream health at locations of primary interest to managers. The goal is to assess if stream health is improving, degrading, or remaining static over time. A targeted monitoring design that focuses on watershed sites that integrate upstream inputs is preferred. To answer this question, we will set up a network of long-term monitoring sites across the region. All coastal watersheds will have at least one long-term monitoring site located at the bottom of the watershed. Additional sites may be located in the interior below major tributaries and other regions of interest. At each site, water chemistry and toxicity will be evaluated at least once per year during dry weather. Ideally, these sites will be co-located at existing sites so that historical data can be used to help assess trends.

SPECIFIC APPROACH

The specific approach to the regional monitoring design is broken into two sections according to design. The first section addresses the first and second questions and is focused on spatial extent. The next section addresses the third question and is focused on trends.

Spatial Extent

The questions regarding spatial extent has several study design characteristics including sampling frame, sample size, frequency, indicators, and methods.

Sampling Frame

Sample sites were selected using a probabilistic approach weighting by watershed, land use, and stream order (Stevens and Olsen 2004). The sampling frame includes 15 watershed units located from Ventura to San Diego and as far east as San Bernardino and Riverside Counties (Figure 1). These watersheds equate to combinations of management units utilized by the RWQCBs or SMC member agencies. Altogether these 15 watershed units are comprised of roughly 28,051 km^2 (Table 2). The streamlines used to define the sampling frame were derived from the National Hydrography Dataset (NHD Plus) (US

EPA and USGS 2007). Altogether, there are 9,492 stream miles of Strahler order 2 and greater in the sampling frame. Land use was defined as either urban, agriculture, or open based on CCAP remote imaging algorithms (National Oceanic and Atmospheric Administration 1995) (Figure 2). CCAP defines 35 different land use classes that have been aggregated into the three categories for this study (i.e., open, agriculture, urban, and water) (Table 3). The dominant land use within a 500-m buffer was assigned to each stream reach. Individual watersheds are described in Appendix 1.

Sample size

Sample size was defined based on the relative effort to obtain estimates of spatial extent with known estimates of precision. These estimates are defined by a power curve from a binomial distribution (Figure 3). In this case, a sample of 30 provides an estimate of spatial extent $\pm$ 12%, which was considered sufficient by managers in this region for making decisions. So, if each watershed requires 30 samples, and there are 15 watersheds, the total sample size for the spatial extent question will be 450 samples (Table 4). Since there are only three land use strata, there will be more than 30 sites in each land use (Table 4). The number of sites representing each land use type reflects the abundance of the land use type within the entire region. Figure 4 shows the distribution of sites in the sample draw, according to watershed and land use.

Frequency

Each site shall be sampled only once during an index period beginning 4 weeks following the last significant rainfall and no more than 12 weeks following the last rainfall. Significant rainfall is defined as precipitation that produces sufficient scouring to disrupt benthic communities. In addition, no sampling shall occur within 72 hours of any measureable rainfall. Based on historical rainfall records, the wet season in southern California ends April 15th (Figure 5). Without apriori knowledge of rainfall, the default index period will occur from May 15 to July 15.

Although all sampling must occur within the index period, not all sites need to be collected during the same year (Table 4). In fact, it is better to collect the sites across multiple years to incorporate the effects of differences in rainfall and subsequent hydrology. What was important to the SMC and SWAMP was to get an answer to the first monitoring question after five years (i.e., one NPDES permit cycle). Therefore, one-fifth of the samples will be collected each year. This equates to six sites per watershed or 90 sites per year total. After five years, a rolling five-year window can be used to assess trends in spatial extent.

Indicators

There are six different types of indicators used answer the question about spatial extent. All of these indicators will be measured in a manner comparable to SWAMP to ensure integration with statewide data sets. The first indicator is water chemistry. Water

chemistry shall include conventional water quality, nutrients, trace metals, and pyrethroid pesticides (Table 5). The water chemistry variables shall be collected and analyzed according to Puckett (2002) and Ode (2005). The second indicator is aquatic toxicity to the water flea, *Ceriodaphnia dubia*. Chronic toxicity shall be measured as a 7-day exposure with effects endpoints of lethality and reproduction according to US EPA (1993). The freshwater amphipod, *Hyalella azteca*, in a water phase text, can be used as a back up species if conductivity is too high for *Ceriodaphnia* control survival. The third indicator is physical habitat that includes several types of measures of stream condition including flow, channel morphology, riparian cover, substrate, and human alterations. Measurements shall be collected according to Ode (2007). The fourth indicator is benthic macroinvertebrates. Benthos shall be collected using the multi-habitat method described in the SWAMP protocol (Ode 2007). Identifications will be done according to the Standard Taxonomic Effort Level 2 for California benthic macroinvertebrates, as described in Richards and Rogers (2007). The fifth indicator is wetland status. Wetland status shall be measured using the California Rapid Assessment Method (CRAM). CRAM is a cost effective diagnostic tool that is part of a comprehensive statewide program to monitor the health of wetlands and riparian habitats throughout California (Collins et al., 2007). The sixth indicator is periphyton. Periphyton, or attached algae, shall be measured in two ways; biomass and taxonomic identification. SWAMP is currently developing standardized methodology for periphyton. In an effort to maintain comparability, the reginal monitoring program shall adopt these same methods.

Trends

The question regarding temporal trends has several study design characteristics including sample sites, frequency, indicators and methods.

Sampling Sites

Sample sites were selected using a targeted approach weighting. The criteria for site selection included: 1) located near the terminus of the stream or river so that it integrates all discharges upstream of the site; and 2) is a previously monitored location so prior data collection can be utilized. One site per watershed examined in the spatial extent design was selected for a total of 15 sites (Figure 1, Table 6). Additional sites can be selected as desired.

Frequency

Sampling frequency is a function of data variability, amount of change to detect, and time to detect change. These three factors are best evaluated using power analysis at each site for each indicator. Based on power analysis from a subset of sites, a minimum of 1 sample per year shall be collected during a dry weather index period from each site (Figure 6). Additional samples may be collected to increase the power to detect trends on

a site-by-site basis. The index period shall match the index period used for the spatial extent question.

Indicators

There are two different types of indicators used answer the question about trends: water chemistry and aquatic toxicity. Both of these indicators will be measured in a manner comparable to SWAMP to ensure integration with statewide data sets. Water chemistry shall include conventional water quality, nutrients, trace metals, PAHs, and pyrethroid pesticides (Table 5). The water chemistry variables shall be collected and analyzed according to Puckett (2002) and Ode (2005). The second indicator is aquatic toxicity to the water flea, *Ceriodaphnia dubia*. Chronic toxicity shall be measured as a 7-day exposure with effects endpoints of lethality and reproduction according to US EPA (1993).

PRODUCTS

There will be four types of products generated for the regional monitoring program. The first product will be a field manual. This manual will document all of the recommended methods for field activities including necessary equipment, sampling protocols, training requirements, field data sheets, and sample site assignments. As part of the field manual, there will be a meeting of all of the field team leaders to ensure consistency and comparability among agencies conducting sampling. One such training and intercalibration occurred in February 2004 and a second in May 2006.

The second product from the regional monitoring program will be a quality assurance manual. The quality assurance manual will document the recommended data quality objectives (DQOs) for field and laboratory activities. The DQOs set minimum standards for sensitivity, accuracy, precision, and representativeness. Only with this level of quality control can data be made comparable enough for compilation. The SMC has already undergone two laboratory intercalibrations and created a laboratory guidance manual for many of the water chemistry constituents required for this workplan.

The third product from the regional monitoring program will be an Information Management (IM) Manual. The IM Manual will be the key document that enables the various agencies share data. The IM Manual will consist of standardized data formats (SDTFs). SDTFs detail the data types and formats (i.e., order of variables) enabling laboratories to deliver complete data sets in any software format, including delimited ASCII code. No new software, hardware, or extensive personnel training is required for SDTFs. The SMC has already created and shared SDTFs for most of the data types being collected in the Regional Monitoring Program (Cooper et al. 2004).

The fourth product from the regional monitoring program will be an assessment report. The assessment report will be a synopsis of the findings of the survey that addresses the

three questions. While there are a large number of potential data products from this type of a survey, a few examples are listed here. To answer the first question, an assessment of stream-miles impacted will be conducted (Figure 7). This will provide a statistically valid answer to the question of overall health of streams regionally. This assessment will include the percent of stream-miles for southern California as a whole and by individual watersheds. A similar data product can be developed, but replacing watersheds with different land uses along the x-axis.

To answer the second question, the relative risk of various stressors will be evaluated by dividing the extent of stream-miles impacted by that stressor by the extent of impacted stream-miles not impacted by that same stressor (Figure 8). Quotients near unity represent limited or no increased risk to aquatic life for that stressor. Quotients greater than one represent an increased risk for that stressor. The greater the quotient, the greater the relative risk. This data can be used to assess the potential risk in future site specific applications, help to determine sources of impact at individual sites, or to help assess important factors in remediation/restoration projects.

To answer the third question, the temporal trends of stream health indicators will be plotted over time to determine if resources are improving, degrading, or remaining unchanged (Figure 9). This will be useful at the watershed specific level to determine if site-specific management actions have been successful at improving water quality impacts. This will also be useful at the regional level to determine if large-scale changes may be influencing local or site specific trends. That is, decreases (or increase) in stream health may be a reflection of large-scale phenomenon such as global warming, nonindigenous species, or other event, rather than watershed specific activities.

SCHEDULE

The regional monitoring program will be a five-year process (Figure 10). Sample preparation, including field and QA manuals will occur prior to the first year of sampling. Sampling will be completed by July and Laboratory analysis should take approximately 6 months. Compiling data, examining results, and making our first year assessments should require approximately three months (March). This will provide sufficient time to use what lessons were learned during year 1 and improve the program for year 2. An oral report of results from the first year will be presented by March, and a written first year report should be completed by June. This process is then repeated each year.

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Table 1. List of member agencies in the Stormwater Monitoring Coalition.

California Regional Water Quality Control Board, Los Angeles Region
California Regional Water Quality Control Board, San Diego Region
California Regional Water Quality Control Board, Santa Ana Region
California Department of Transportation, Caltrans
City of Long Beach
City of Los Angeles, Watershed Protection Division
County of Orange, Public Facilities and Resources Dept.
County of San Diego Stormwater Management Program
Los Angeles County Department of Public Works
Riverside County Flood Control and Water Conservation District
San Bernardino County Flood Control District
Southern California Coastal Water Research Project
State Water Resources Control Board
US Environmental Protection Agency, Office of Research and Development
Ventura County Watershed Protection District

Table 2. Watersheds included in the monitoring program.

Watershed	Area (km^2)	Stream order	Total stream length (km)	Land use by area (proportion)			
				Open	Agricultural	Urban	Water
Ventura	642	6	264	0.88	0.05	0.05	0.03
Santa Clara	4,327	7	1,763	0.85	0.07	0.05	0.03
Calleguas	891	5	391	0.46	0.31	0.21	0.03
Santa Monica Bay	1,171	4	260	0.59	0.03	0.37	0.06
Los Angeles	2,160	5	626	0.44	0.02	0.53	0.06
San Gabriel	1,758	5	586	0.49	0.02	0.47	0.05
Santa Ana River	7,092	6	2,202	0.58	0.10	0.29	0.04
--Lower Santa Ana	1,253	6	349	0.35	0.06	0.54	0.07
--Middle Santa Ana	2,135	6	622	0.43	0.13	0.41	0.04
--Upper Santa Ana	1,721	5	654	0.78	0.04	0.15	0.03
--San Jacinto	1,984	4	576	0.71	0.14	0.12	0.02
San Juan	1,019	4	400	0.75	0.03	0.19	0.03
Northern San Diego	3,640	6	1,299	0.80	0.12	0.06	0.02
Carlsbad	1,725	5	513	0.57	0.08	0.32	0.04
Mission Bay	1,270	5	390	0.71	0.03	0.23	0.04
Southern San Diego	2,355	5	798	0.78	0.04	0.15	0.04
Entire region	28,051	7	9,492	0.66	0.08	0.23	0.03

Table 3: Land use classes defined by the SMC and CCAP.

SMC class	CCAP class
Agriculture	Cultivated Land
Agriculture	Managed Grassland
Agriculture	Orchards
Agriculture	Pasture
Agriculture	Row Crop
Open	Bare Land
Open	Chaparral
Open	Deciduous Forest
Open	Estuarine Emergent Wetland
Open	Estuarine Forested Wetland
Open	Estuarine Scrub/Shrub Wetland
Open	Evergreen Forest
Open	Golf Courses
Open	Mixed Forest
Open	Palustrine Emergent Wetland
Open	Palustrine Forested Wetland
Open	Palustrine Scrub/Shrub Wetland
Open	Parks / Lawns
Open	Rangeland
Open	Sage
Open	Scrub/Shrub
Open	Unmanaged Grassland
Urban	Commercial/Industrial
Urban	High Intensity Developed
Urban	High Intensity Urban Residential
Urban	Low Intensity Developed
Urban	Rural Residential
Urban	Suburban Residential
Urban	Urban Residential
Excluded	Background
Excluded	Estuarine Aquatic Bed
Excluded	Palustrine Aquatic Bed
Excluded	Unclassified
Excluded	Unconsolidated Shore
Excluded	Water

Table 4. Projected number of samples by year.

Year	Number of samples in all watersheds	Number of samples in each watershed	Number of samples by land use		
			Open	Agriculture	Urban
2009	90	6	40	15	35
2010	90	6	28	21	41
2011	90	6	36	21	33
2012	90	6	28	32	30
2013	90	6	30	28	32
Total after five years	450	30	162	117	171

Table 5. Variables measured at each site in the. P = variables measured at sites included in the probabilistic components of the project (i.e., questions 1 and 2). T = variables measured at sites included in the network of long-term trends sites.

Variable	P/T	Method	Accuracy	Precision	Reporting Limit
Biological					
Benthic macroinvertebrates	P	Ode 2007	Re-sort frequency: 100% Re-sort accuracy: ≥95% Lab ID frequency: 10% Lab ID Accuracy: ≥95%	Field duplicates: 10%	SAFIT Level 2
Periphyton: Chlorophyll a Ash-free dry mass Taxonomy	 P P P		 ±20% of SRM. NA Diatoms,archive macroalga	Field duplicates: 10%	 10 μg/cm^2 1 mg/ cm^2
Riparian condition (CRAM)	P	Collins 2007			
Toxicity					
Ceriodaphnia dubia assays	P,T	EPA 1993	NA	Lab duplicates 10%	NA
Water Chemistry					
Conventional water chemistry Temperature pH Conductivity Dissolved oxygen Alkalinity Hardness	P,T	 Probe Probe Probe Probe	 NA ± 0.5 units of SRM ±5% of SRM ±0.5 mg/L of SRM ±10% of SRM	 ± 0.5 C ± 0.5 units ±5% ±0.5 mg/L ±10%	 NA 0 - 14 pH units 2.5 mS/cm 0.5 mg/L 10 mg/L
Nutrients Ammonia Nitrite Nitrate Total nitrogen Orthophosphate Total phosphorous	P,T		Within 80% to 120% of true value	Field replicate, laboratory duplicate 10%, or MS/MSD ± 25% RPD. Laboratory duplicate minimum.	 0.1 mg/L 0.01 mg/L 0.1 mg/L 0.1 mg/L 0.01 mg/L 0.1 mg/L
Major ions Calcium Sulfate	P,T		Within 80% to 120% of true value	Field replicate, laboratory duplicate 10%, or MS/MSD ±	 0.05 mg/L 0.25 mg/L

					25% RPD. Laboratory duplicate minimum.	
	Metals (dissolved and Total) Arsenic Cadmium Chromium Copper Iron Lead Nickel Zinc	P,T	EPA 200.8	Within 80% to 120% of true value	Field replicate, laboratory duplicate, or MS/MSD ± 20% RPD. Laboratory duplicate minimum.	 1.0 µg/L 0.5 µg/L 1.0 µg/L 1.0 µg/L 10 µg/L 1.0 µg/L 1.0 µg/L 1.0 µg/L
	Organic constituents Pyrethroid pesticides Organophosphate pesticides PCBs PAHs	 P,T T T T	 8081/82 EPA 8270	50% to 150% of true value.	Field replicate or MS/MSD ± 25% RPD. Field replicate minimum.	 ng/L ng/L 1.0 ng/L 0.5 – 1.0 ng/L
Physical habitat						
	Location (latitude and longitude) Channel dimensions Channel substrate Embeddedness Gradient and sinuosity Human influence Riparian vegetation Instream habitat complexity Flow habitats Discharge Rapid bioassessment scores Additional habitat characterization		Ode 2007	NA	NA	10^{-5}° 1 cm 1 mm NA NA NA NA NA NA NA NA NA

SRM: Standard Reference Material
CI: Confidence Interval
MS: Matrix Spike
MSD: Matrix Spike Duplicate
RPD: Relative Percent Difference
NA: Not applicable

Table 6. List of trend monitoring sites.

Watershed	Stream	Location
Ventura	Ventura River	at Foster Park
Santa Clara	Santa Clara River	Freeman Diversion
Calleguas	Calleguas Creek	at University Drive
Santa Monica Bay	Ballona Creek	at Sawtelle
Los Angeles	Los Angeles River	at Willow
San Gabriel	San Gabriel River	R9W
San Gabriel	San Gabriel River	R9E
Lower Santa Ana	San Diego Creek	at Campus Drive
Middle Santa Ana	Santa Ana River	at River Road
Upper Santa Ana	Santa Ana River	MWD Crossing
San Jacinto	San Jacinto River	at Goetz/TMDL site
San Juan	San Juan Creek	at Novia
Northern San Diego	Santa Margarita	at Basilone
Carlsbad	Escondido Creek	at Mass Emissions Site
Mission Bay	San Diego River	at Fashion Valley Rd
Southern San Diego	Tijuana River	at Hollister Rd

Figure 1. Map of watersheds included in the regional watershed monitoring program.

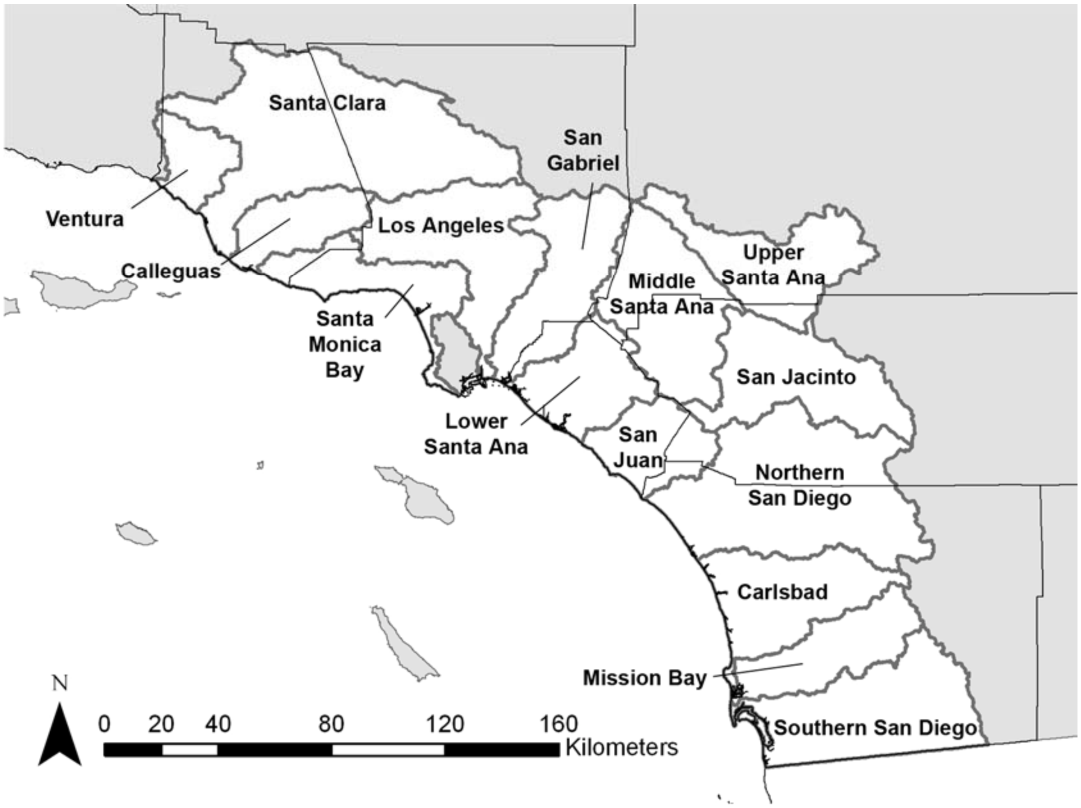

Figure 2. A. CCAP remote imaging of land use in the southern California region. B. Land use assignments for the watersheds included in the study.

A

B

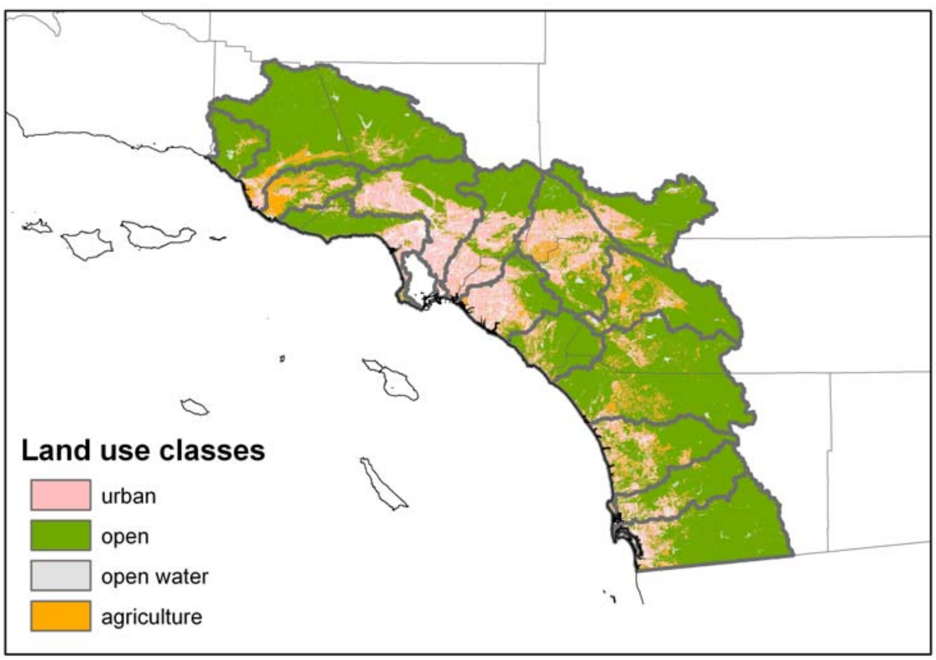

Figure 3. Size of confidence intervals about areal estimates (i.e., percent stream-miles) for different sample sizes.

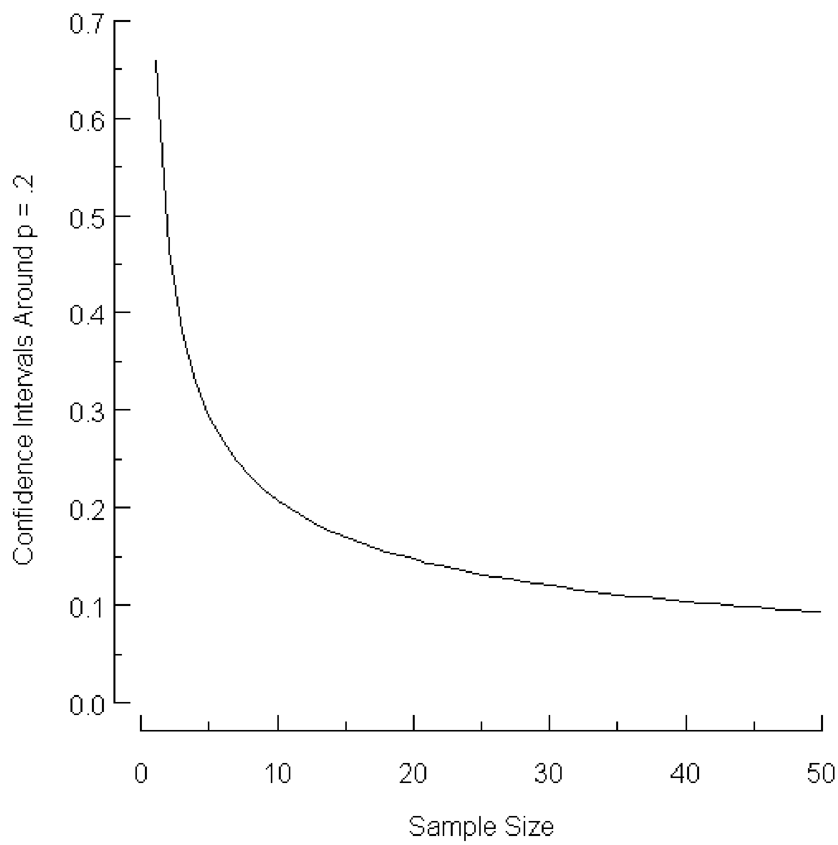

Figure 4. Locations of sample sites for the SMC regional watershed monitoring program.

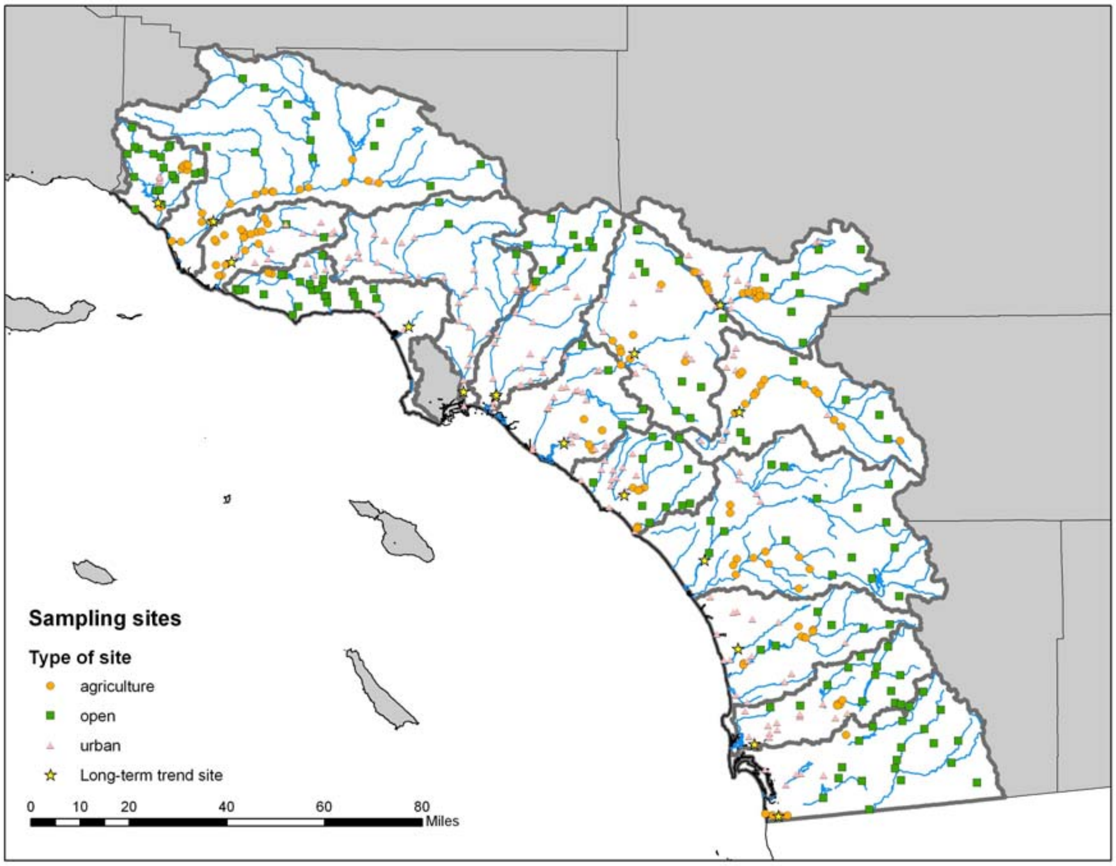

Figure 5. Avergae monthly rainfall quantities at Lindbergh Field, San Diego from 1905 to 2006.

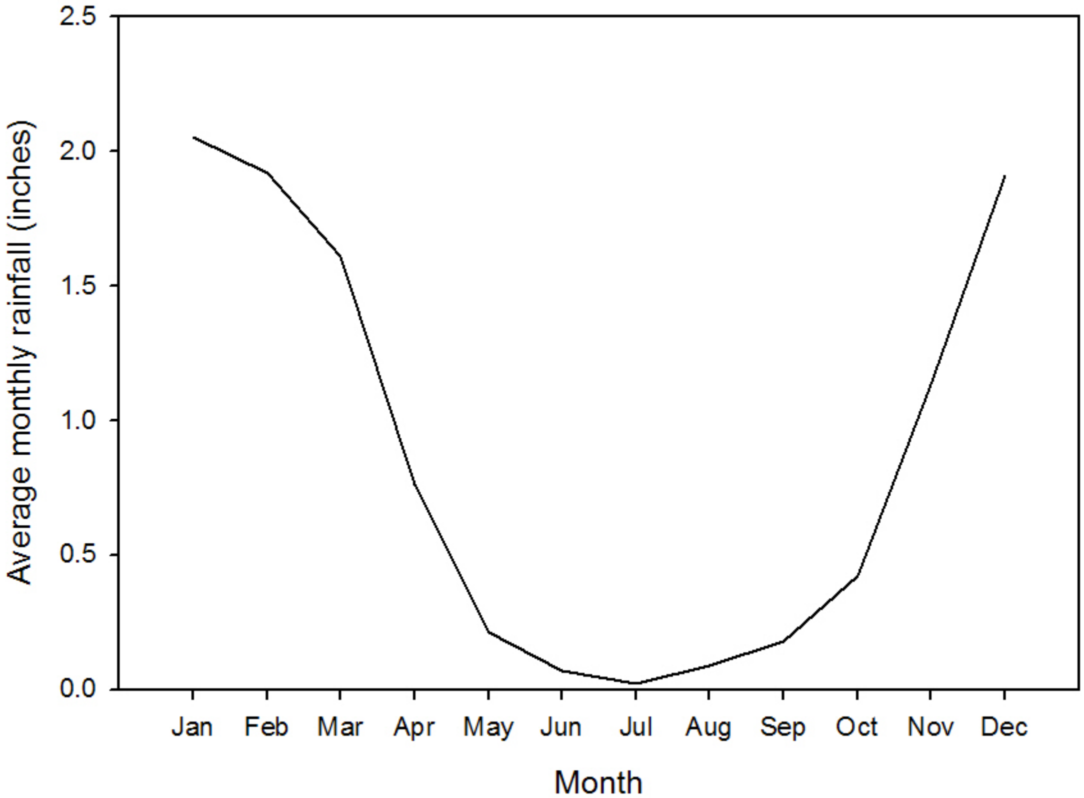

Figure 6. Power curves to detect changes in a constituent at a long-term monitoring site (Hemet NPDES site in Riverside County). The right-most solid line represents power of one sample per year; from left to right, the remaining samples represent 2, 3, and 4 samples per year. [

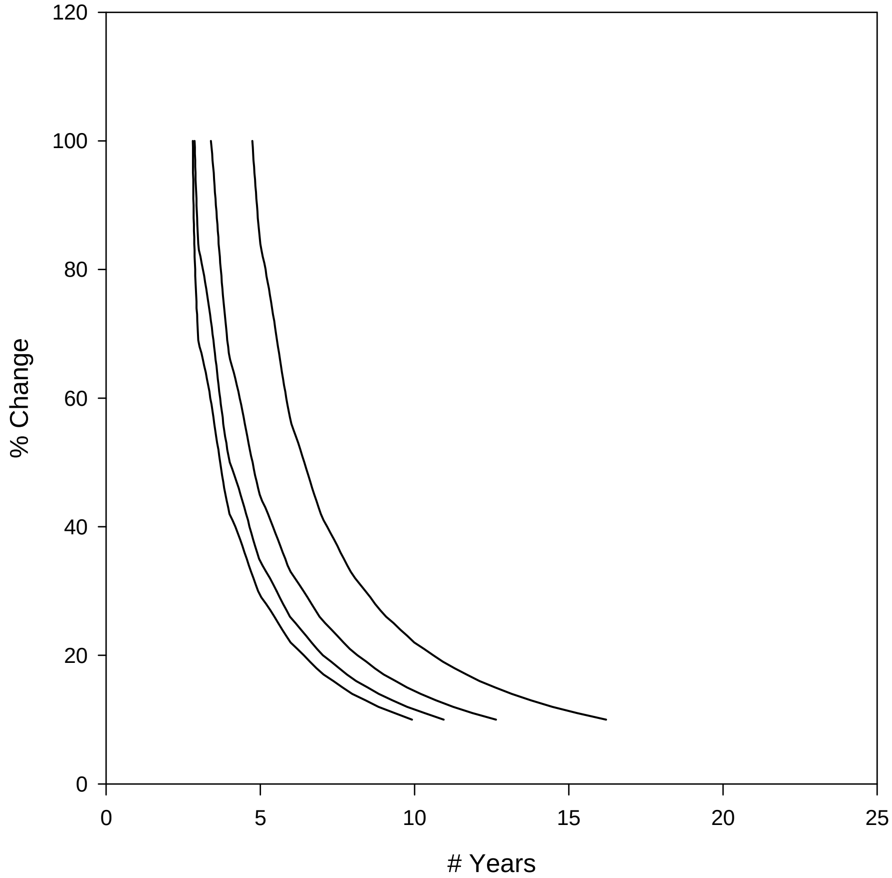

Figure 7. Hypothetical distribution of degraded stream miles among different watersheds.

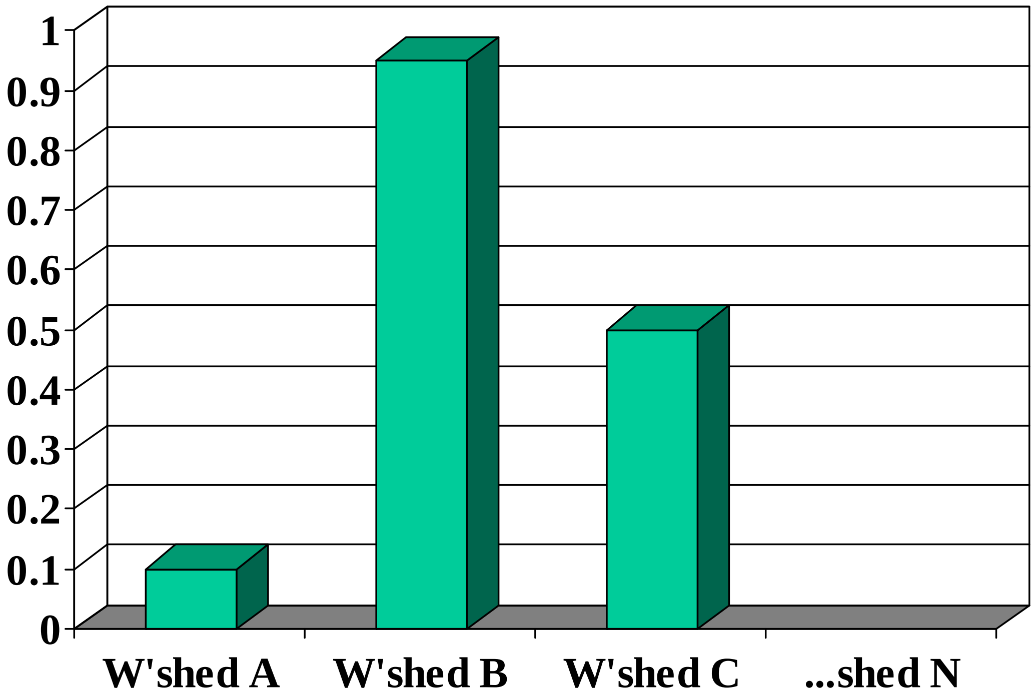

Figure 8. Hypothetical relative risks for stressors to an indicator. Relative risk is the quotient of extent (as %) of stream miles impaired by stressor x in an anthropogenic stratum and the extent of stream miles (as %) of stream miles impaired by stressor x in open (or reference) stratum.

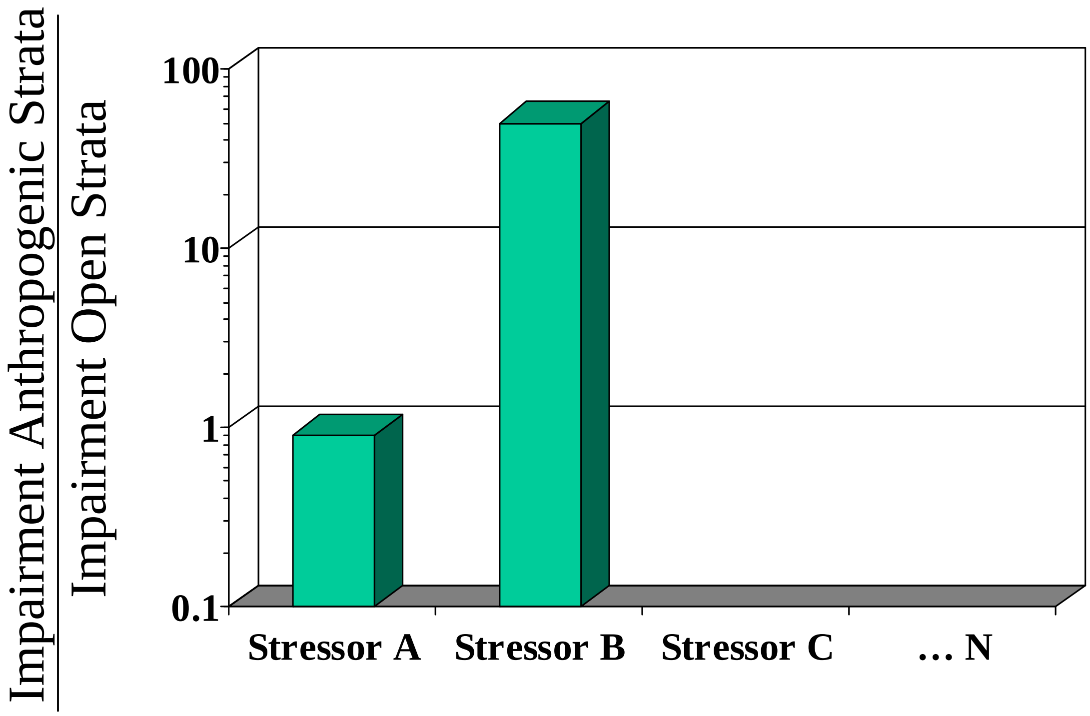

Figure 9. Hypothetical trends in a constituent measured at a trends site. Points reflect differences in values relative to Year 1 values at an integrator site.

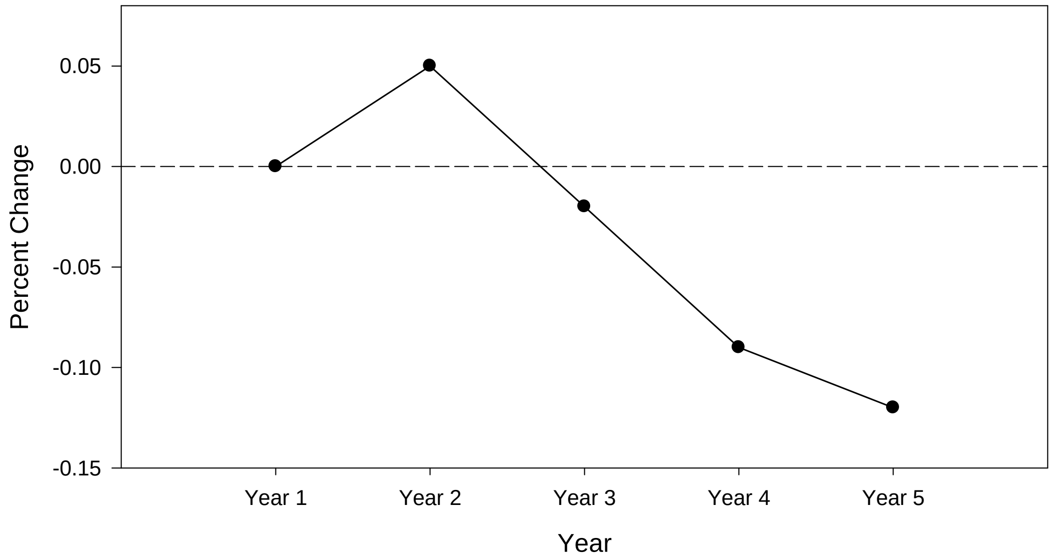

Figure 10. Timeline of activities through the first two years